

APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

**Method And Apparatus  
For Reusing Subparts Of One Mechanical Design For Another  
Mechanical Design**

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"Express Mail" label number EL034432036US

"Express Mail" mailing label number EL134432036US  
Date of Deposit January 28, 1999

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**Method and Apparatus for Reusing Subparts Of One Mechanical Design In  
Another Design**

**BACKGROUND OF THE INVENTION**

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1. Field of the Invention

The present invention relates to the field of computer aided design (CAD). More specifically, the present invention relates to reusing subparts of one 10 mechanical design in another mechanical design.

2. Background Information

Prior art CAD tools typically describe a mechanical design in terms of 15 various geometric shapes, also referred to as "parts". Each part in turn is expressed as a step-by-step ~~recipe~~ incrementally building the various features of the geometric shape, with each step roughly corresponds to a feature. In other words, each part is formed through a linear sequence of steps. For example, a linear step sequence 20 may specify a particular geometric shape is to be formed by starting with a block, cutting a slot at a first location (a first feature), then cutting another angled slot at a second location (a second feature), and so forth. By changing the different design parameters of the "recipe", different embodiments of the geometric shape may be built.

25 The prior art linear sequence approach to modeling geometric shapes of a mechanical design suffers from at least a number of disadvantages:

a) a significant number of topics or issues associated with the modeling of a mechanical design can not be expressed as features, e.g. equations to create cost, stress and so forth;

b) linear sequences are difficult to manipulate and re-order; and

5 c) linear sequences do not adapt well to reuse analysis, i.e. the reuse of a subpart of one mechanical design in another mechanical design.

The fact that linear sequences do not adapt well to reuse analysis is especially problematic for CAD tools, as increasingly, mechanical designers desire

10 to be able to reuse various subparts of their mechanical designs, in particular, the "standard" or "common" building block subparts employed in otherwise highly complex mechanical designs. Thus, a more effective and efficient approach to expressing mechanical designs and facilitating manipulation of the mechanical designs to allow different subparts of one mechanical design to be easily reuse in

15 another, is desired.

## SUMMARY OF THE INVENTION

A mechanical design reuse method includes having a CAD tool  
5 replicates a subset of a first modeling representation of a first mechanical design, in  
response to having received instructions that identify a subpart of the first  
mechanical design. The reuse method further includes having the CAD tool merges  
the replicated subset into a second modeling representation of a second mechanical  
design to effectuate the reuse of the identified subpart of the first mechanical design  
10 in the second mechanical design.

In one embodiment, the modeling representations are dependent  
graphs, and the subsets being replicated and merged are sub-graphs of the  
dependent graphs. The dependent graphs and sub-graphs include nodes directly  
15 associated with subparts of the mechanical designs, nodes the directly associated  
nodes are dependent on, and arcs linking these nodes together in accordance with  
their dependency on one another. In one embodiment, the replicate and merging  
process also provides for a designer the option to transform certain design variables  
having constant values assigned to become design variables eligible to have their  
20 values variably assigned, and vice versa.

BRIEF DESCRIPTION OF DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

5 **Figure 1** illustrates an overview of the present invention in accordance with one embodiment;

**Figures 2a-2c** illustrate a mechanical design, its data and its dependent graph in accordance with one example;

10 **Figure 3** illustrate the method of the present invention for viewing a mechanical design and its dependent graph in accordance with one embodiment;

**Figure 4** illustrates the method of the present invention for reusing subparts of a mechanical design in another mechanical design in accordance with one embodiment; and

15 **Figure 5** illustrates one embodiment of a computer system suitable for programming with instructions implementing the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, various aspects of the present invention will be described. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some or all aspects of the present invention.

5 For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well known features are

10 omitted or simplified in order not to obscure the present invention.

Parts of the description will be presented in terms of operations performed by a computer system, using terms such as data, flags, bits, values, characters, strings, numbers and the like, consistent with the manner commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. As well understood by those skilled in the art, these quantities take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through mechanical and electrical components of the computer system; and the term computer system include general

15 purpose as well as special purpose data processing machines, systems, and the like, that are standalone, adjunct or embedded.

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Various operations will be described as multiple discrete steps in turn, in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed

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in the order of presentation. The phrase "in one embodiment" will be employed from time to time, and it is not intended to necessarily refer to the same embodiment.

Referring now **Figure 1**, wherein a block diagram illustrating an

5 overview of the present invention in accordance with one embodiment is shown. As illustrated, CAD tool **100** includes modeler **102** and browser **104**. As in prior art, modeler **102** models mechanical designs (hereinafter, simply designs), while browser **104** facilitates display of the modeled designs and related information for the designer, as well as facilitates input by the designer. However, unlike prior art, 10 in accordance with the present invention, modeler **102** models designs employing dependent graphs, and using data **106a-106b** suitably organized for the dependent graph approach, to be described more fully below, whereas browser **104** not only facilitates display of the designs **108a-108b** and their dependant graphs **110a-110b**, but facilitates their displays in a novel coordinated manner. As will be readily 15 apparent from the description to follow, the present invention advantageously enables a designer to be able to efficiently reuse subparts of one design in another design. In particular, the present invention advantageously enables a designer to be able to efficiently explore the interrelationship between various subparts of a modeled design and its dependant paragraph, thereby allowing the designer to 20 efficiently leverage on the reuse support offered by CAD tool **100**.

Except for the teachings of the present invention incorporated, modeler **102** and browser **104** are otherwise intended to represent a broad range of these elements known in the art. Thus, except for the teachings incorporated, which 25 are described in more details below, modeler **102** and browser **104** will not be otherwise further described.

Referring now to **Figures 2a-2c**, wherein three diagrams illustrating the relationship between an example modeled design, its data and dependent graph, in accordance with one embodiment, are shown. As illustrated in **Fig. 2a**, example design **200** is a simple rectangle having four sides A through D. **Fig. 2b**, illustrates example dependent graph **202** employed by modeler **102** to model design **200**. As illustrated, example dependent graph **202** includes nodes **204**, nodes **206**, and arcs **208** linking nodes **204** and **206** to one another. Nodes **204** and **206** represent “atomic” design variables of example design **200**, i.e. they represent the “lowest level” information building blocks for modeling example design **200**.

Examples of these “lowest level” information building blocks are numbers, lines, points, and so forth. Nodes **204** are referred to as independent nodes representing independent design variables, whereas nodes **206** are referred to as dependent nodes representing dependent design variables. Dependent design variables are those design variables that cannot be resolved until other design variables are resolved first. Thus, arcs **208** represent dependencies between the design variables represented by nodes **204** and **206**. For example, nodes **206** directly representing lines A-D of rectangle **200** are linked to nodes **204** defining lines A-D’s dimension, as well as to one another, by arcs **208** representing the “length of”, perpendicular, and parallel relationships between these nodes. Two example types of “dimension” nodes **204** are illustrated, “3 cm” and “<user input>”. Nodes **206** linked to “3 cm” node **204** represent the length of the lines represented by the particular nodes **206** are invariantly assigned the value “3 cm”, whereas nodes **206** linked to “<user input>” node **204** “represent the length of the lines represented by the particular nodes **206** are eligible to have their lengths variably assigned by the designer.

As shown in **Fig. 2c**, for the illustrated embodiment, the descriptive data of example design **200** processed by modeler **102** to generate dependent graph **202** are organized in a tabular manner. As those skilled in the art will appreciate that any one of a number of other known data organizations may also be employed to store the descriptive data of a design.

Furthermore, while for ease of understanding, the interrelationships between a design, its data and its dependent graph have been illustrated with the simple example design of a rectangle, as those skilled in the art will appreciate that the principles are nevertheless fully scalable to highly complex designs having large quantities of data and complicated dependent graphs.

Referring now to **Figure 3**, wherein a flow diagram illustrating the operational flow of browser **104** for facilitating exploration of a modeled design and its dependent graph, in accordance with one embodiment, is shown. As illustrated, at **302**, browser **104** receives certain selection inputs from the user. The selection may be denoted and communicated to browser **104** in any one of a number of techniques known in the art, e.g. using a cursor control device and posting messages for browser **104** responsive to certain predetermined cursor control device events. In response, at **304**, browser **104** determines whether the selections were made in reference to the design displayed **108a/108b** or in reference to their dependent graphs **110a/110b**. The determination may also be made in accordance with any one of a number of techniques known in the art, e.g. by having the messages include identification information of the "focus" window at the time the cursor control device events arose.

If it is determined at 304 that the selections were made in reference to the design displayed 108a/108b, at 306, browser 104 identifies the dependent graph nodes that are directly associated with the subpart of the mechanical design 5 selected. Additionally, at 308, browser 104 further identifies all other dependent graph nodes to which the directly associated nodes are dependent on, directly or indirectly, and the arcs that link these nodes to one another. The identification process may be implemented using any one of a number of known "tracing" techniques, to systematically follow the arcs to all the independent nodes on which 10 the directly associated nodes are dependent on. At 310, browser 104, refreshes dependant graph display 110a/110b to reflect the nodes and arcs identified.

Similarly, If it is determined at 304 that the selections were made in reference to the dependent graph displayed 110a/110b, at 312, browser 104 15 determines whether the graphical elements selected are directly associated with specific subparts of the mechanical design. If the graphical elements selected are not directly associated with specific subpart of the mechanical design, at 314, browser 104 follows the arcs radiating from the selected graphical elements to identify the "nearest" directly associated nodes. Upon either having received 20 identifications of the directly associated nodes directly, or determined the directly associated nodes, at 316, browser 104 refreshes design display 108a/108b to highlight the directly associated subparts.

Operations 302-316 may be repeated as many times as it is 25 necessary, alternating between the two basic paths as desired, i.e. selecting subparts of a design and selecting graphical elements of the dependent graph, to

facilitate a designer in exploring and understanding a design. As those skilled in the art will appreciate, the above described novel coordinated approach to facilitate viewing of a design and its dependent graph is particularly useful for facilitating a designer in exploring the various subparts of a design, and reusing selected ones of

5 the subparts in another design.

Referring now to **Figure 4**, wherein a flow diagram illustrating the operational flow of modeler 102 for facilitating reuse of a subpart of one design in another design, in accordance with one embodiment, is shown. As illustrated, at

10 402, modeler 102 receives (e.g. by way of browser 104) certain design subpart reuse related identification inputs from the user. In response, modeler 102, at 404, determines whether the inputs are associated with the identification of a subpart of one design to be reused in another design, or the inputs are associated with the identification of a point or an area of a target design on which a subpart of another

15 design is to be inserted or reused.

If it is determined at 404 that the inputs are associated with the identification of a subpart of one design to be reused in another design, at 406, modeler 102 further determines if the inputs were provided referencing the dependent graph or the modeled design itself. If it is determined at 406 that the

20 inputs were provided referencing the modeled design itself, at 408, modeler 102 first identifies the dependent graph nodes directly associated with the selected subpart of the design to be reused. If it is determined at 406 that the inputs were provided referencing the dependent graph or upon identifying the directly associated nodes at 408, at 410, modeler 102 identifies the dependent graph nodes on which the directly

25 associated nodes are dependent, directly as well as indirectly, and the arcs linking

these nodes to one another. As described earlier, the determination process may be implemented using any one of a number of known “tracing” techniques, to systematically follow the linking arcs to the independent nodes on which the directly associated nodes are dependent. Once all the dependent and independent nodes,

5 and the arcs linking them are identified for the selected subpart to be reused, at **412**, modeler **102** replicates the sub-graph, i.e. creating a copy of the identified dependent and independent nodes, and their linking arcs.

Having replicated the sub-graph, at **414**, modeler **102** determines if the

10 insertion points in the dependent graph of the target design have been determined. If the insertion points have not been identified, at **416**, modeler **102** in cooperation with browser **104** prompts the user to identify the point or area where the subpart is to be reused (i.e. inserted). If the insertion points have been identified, at **418**, modeler **102** attaches the replicated sub-graph to the dependent graph of the target 15 design to reuse the selected subpart with the target design. Lastly, at **420**, modeler **102** refreshes target design's display **108a/108b** as well as the dependent graph display **110a/110b**.

Back at **404**, if it was determined that the inputs received were

20 associated with identifying the insertion point or area of a target design, at **422**, modeler **102** further determines whether the inputs were provided referencing target design's display **108a/108b** or referencing its dependent graph display **110a/110b**. If the inputs were provided referencing target design's display **108a/108b**, at **424**, modeler **102** first identifies the dependent graph nodes directly associated with the

identified insert point or area of the target design. Upon either determining that the inputs were provided referencing the dependent graph or having identified the dependent graph nodes directly associated with the insertion point/area, at **426**, modeler **102**, further identifies other dependent graph nodes on which the 5 identified/directly associated insertion point nodes are directly or indirectly dependent, and the arcs linking these nodes to each other.

Having identified the insertion points in the dependent graph of the target design, at **428**, modeler **102** determines if the sub-graph modeling the subpart

10 to be reused has been generated (i.e. replicated). If the sub-graph has not been generated, at **430**, modeler **102** in cooperation with browser **104** prompts the user to identify the subpart to be reused. Upon receipt of the identification of the subpart to be reused, the process continues as described earlier. If the sub-graph has been generated, modeler **102** proceeds with the attachment and refresh operations of **418** 15 and **420** as described earlier.

In one embodiment, modeler **102** further provides a user with the opportunity to transform selected ones of the design variables (nodes) from having assigned constant values to being eligible to have their values variably assigned, or

20 vice versa. In one embodiment, modeler **102** offers the transformation option to the user, one applicable design variable at a time, as it processes the independent nodes while performing attachment operation **418**.

Figure 5 illustrates one embodiment of a computer system suitable to be programmed with programming instructions implementing the CAD tool incorporated with the teachings of the present invention. As shown, for the illustrated embodiment, computer 500 includes processor 502, system bus 506 and 5 I/O bus 510. System bus 506 and I/O bus 510 are bridged by bus bridge 508. Coupled to system bus 506 are system memory 514 and video memory 516, against which video display 518 is coupled. Coupled to I/O bus 510 are disk drive 522, keyboard and pointing device 524, and communication interface 526. Most importantly, computer 500 is programmed with CAD tool 100 incorporated with the 10 teachings of the present invention as described earlier, and operating system 550.

The elements perform their conventional functions known in the art, except CAD tool 100 perform its otherwise conventional functions in accordance with the present invention. In particular, disk drive 522 and system memory 514 are 15 used to store permanent and working copies of CAD tool 100 and operating system 550, and video display 518 is used to display e.g. design displays 108a/108b and dependent graph displays 110a/110b.. The permanent copies may be pre-loaded into disk drive 522 in a factory, loaded from distribution medium 532, or down loaded from a remote distribution source (not shown). Distribution medium 532 may be a 20 tape, a CD, a DVD or other storage medium of the like. The constitutions of these elements are known. Any one of a number of implementations of these elements known in the art may be used to form computer system 500. In alternate embodiments, other components may also be used in addition to or in lieu of the components described, e.g. additional processors. In selected ones of these multi- 25 processor embodiments, execution of the programming instructions implementing

CAD tool 100 incorporated with the teachings of the present invention may also be distributed among the processors.

In general, those skilled in the art will recognize that the present  
5 invention is not limited by the details described, instead, the present invention can be practiced with modifications and alterations within the spirit and scope of the appended claims. The description is thus to be regarded as illustrative instead of restrictive on the present invention.

10 Thus, a method and an apparatus for reusing a subpart of one mechanical design in another mechanical design have been described.

65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100